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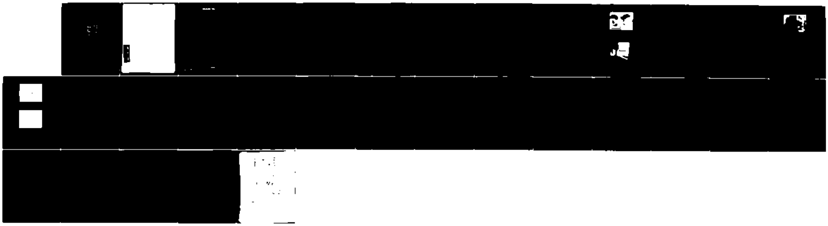

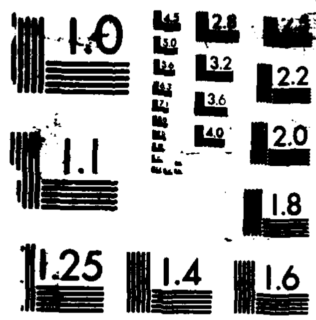

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

To assess and evaluate the utility of Flexible Fiber Optics Bundles (FFOB) as image transmitters, a study was performed to determine what effect the number of active fibers across a given symbolic character would have on the legibility of that character. Twelve subjects performed a symbol identification task in which the symbols were displayed through either a rectangular or a hexagonal format FFOB. The symbols viewed varied in terms of the number of elements per letter height and in angular subtense. Subject performance was evaluated in terms of correct identifications, response times for correct identifications, misses, and false identifications. Major findings of this study indicate that (1) performance with the hexagonal bundle was superior to that with the rectangular bundle, and (2) performance improv.d as the number of elements per letter height increased, near optimal performance occurring at 8.7 elements or more and angular subtenses greater than 18 minutes of arc. The latter finding compares favorably with findings in the relevant literature.


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# PREFACE

This report was prepared by the Crew Systems Effectiveness Branch, Human Engineering Division, Armstrong Aerospace Medical Research Laboratory (AAMRL), Wright-Patterson Air Force Base, Ohio under Project 7184, Task 718411, Work Unit 7184-11-46, "Advanced VCS and Display Concepts." The authors wish to express their sincere thanks and appreciation to the following individuals who contributed to the successful completion of this effort: Martha Hausmann, who collected and analyzed the data; Rick Hubbard, who prepared the stimulus imagery used in the experiment; and last but not least, Alan Pinkus, who was responsible for setting up and calibrating the experimental apparatus.

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## Section 1

## INTRODUCTION AND BACKGROUND

The Armstrong Aerospace Medical Research Laboratory (AAMRL) has long been involved in the evolution and development of Helmet Mounted Display (HMD) systems. The objectives underlying the development of such systems are (1) the need for a large field-of-view cockpit display which occupies a small space and is lightweight; and (2) the need for developing an off-boresight display capability that can provide information to the operator regardless of his head position/viewing angle. Attainment of these goals would (1) eliminate space and weight as critical engineering design factors in determining permissible size and location of cockpit CRT displays; and (2) greatly reduce operator workload under mission conditions that call for off-boresight target acquisition, tracking and weapon delivery.

Present design concepts for HMDs involve mounting a miniature 1-inch diameter CRT and an appropriate optical train (to transmit the image from the CRT screen to the observer's eye) on the observer's helmet. Unfortunately, this results in undesirable weight being added to the helmet and hence, placed on the pilot's head. Additionally, displacement of the helmet's center-of-gravity (CG) may occur resulting in strain being placed on the pilot's head and neck. Finally, a potential safety problem may occur from mounting a high voltage (5,000 to 7,000 volts) CRT on the helmet. For example, should a ground emergency

occur, the wires to the helmet must be quickly disconnected to permit rapid egress. Such emergencies can involve fuel fumes which could be ignited by sparks when disconnecting the high voltage line.

These problems can be minimized or eliminated if the CRT is not mounted on the helmet. One means of accomplishing this is to use a Flexible Fiber Optic Bundle (FFOB) as an image transmitter between the CRT mounted off the helmet and the helmet optics. A diagram of such an arrangement is shown in Figure 1. Removing the CRT from the helmet affords a further advantage in that it provides more flexibility in selecting the CRT used for the image source. For example, since the CRT would no longer have to be extremely small and light, a slightly larger color CRT could be used. Figure 2 shows two current HMD designs with the CRT mounted on the helmet while Figure 3 presents the FFOB HMD concept.

Although utilization of a FFOB will minimize or eliminate the problems identified, certain disadvantages arise from its use. These include (1) the occurrence of broken fibers causing loss of video information, (2) loss of resolution due to limitations on the number of fibers that can be placed in a bundle and still retain flexibility, (3) more "debris imaging surfaces" being viewed by the observer due to having image planes at both ends of the FFOB, and (4) light loss -- a typical FFOB usually loses approximately 10% of the input light per foot and about 20% at each end.

To determine the feasibility of the FFOB HMD concept, a study was performed in 1974 by Task and Hornseth in which they compared the target search and detection performance of observers using a panel mounted display, an HMD (Honeywell Mod 7A), and a FFOB HMD. Using average slant range to detection and average number of targets detected as their measures of performance, the FFOB HMD was found to yield significantly worse performance than the panel display or conventional HMD. Despite the negative findings towards the FFOB HMD, these investigators recommended the use of a FFOB when considering a color HMD or a symbology-type (eg, a Head Up Display) display.

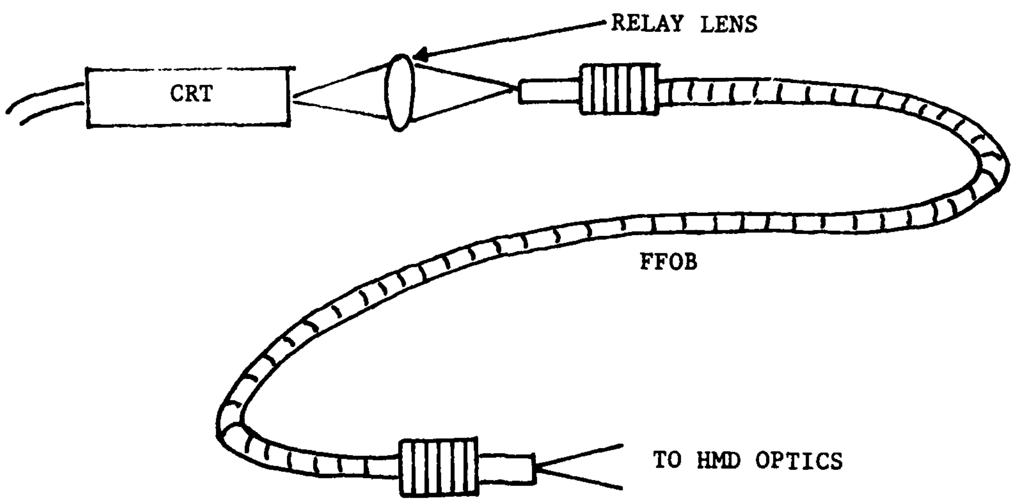


**Figure 1. Diagram of FFOB HMD**

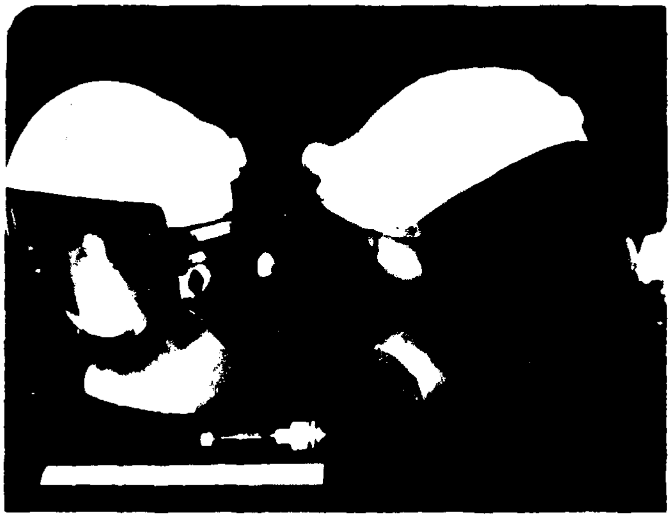

Figure 2. Conventional HMDs. The Hughes Sidemounted HMD (left) and the Honeywell Model 8 Visor HMD (right).

Figure 3. The FFOB HMD concept using a modified Honeywell Model 7A HMD.

## Section 2

## OBJECTIVE

Using the Task and Hornseth study as a point of departure, a program of research was initiated to assess and evaluate the utility of FFOBs as image transmitters for application to HMD systems. The objective of this study was to determine the effect of the number of active fibers across a given symbolic character on the legibility/readability of that character. This study was done using both hexagonal-packed and rectangular packed fiber optic bundles.

## Section 3

## METHODOLOGY

### Apparatus

The apparatus used consisted of three major pieces of equipment -- a 35 mm random access carousel slide projector, a monocular microscope, and two FFOBs. The slide projector served as the image source and was used to randomly present the fifty (50) different stimulus letters to the subjects.

The microscope served as the subject's "display" and was also used to vary the magnification of the alphabetic characters viewed by the subjects. Using three different objective lens sizes (5x, 10x and 20x) in combination with either a 1x or 2.5x eyepiece, magnification levels of 10x, 12.5x and 20x were achieved and used in this study.

The FFOBs were used to transmit the projected image from the slide projector to the microscope. One bundle consisted of 10-micron fibers arranged in a 5 x 5 mm rectangular format while the other bundle consisted of 50-micron fibers arranged in a 5 mm hexagonal format.

Additional equipment used included a microcomputer (which selected the order of presentation of the various stimulus slides), a digital timer (used to measure subject's response time), and a lens (used to image the stimulus slide onto the FFOB). The equipment used and their relationship to one another are shown in Figure 4.

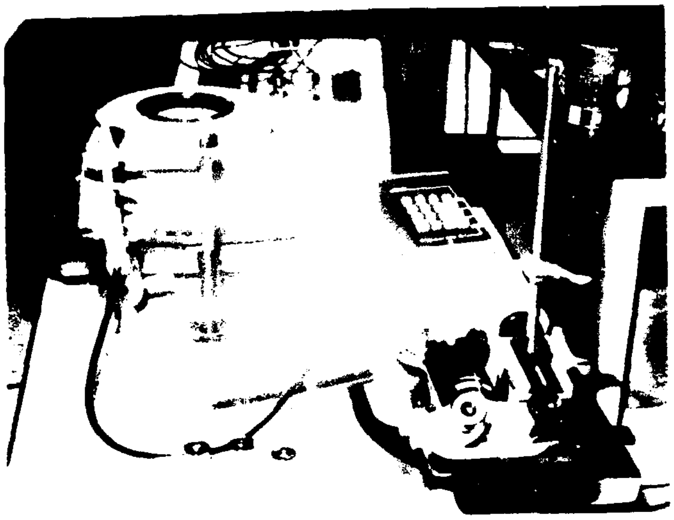

Figure 4. The equipment used in the study.

Stimulus Slides

Ten alphabetic characters (D, E, F, G, L, N, O, P, V and Z) were selected for use as the stimulus imagery. Fifty 35 mm slides were prepared consisting of 5 different sizes of each of the 10 characters selected. The 5 different character sizes (angular subtense) were calculated by taking the number of elements across a given letter and multiplying it by the individual fiber element angular subtense. This resulted in the character angular subtense shown in Table 1 for both the rectangular and hexagonal formatted bundles. Due to the differences in the size of the fibers for the rectangular and hexagonal bundles (10 micron vs 50 micron), it can be seen that the character angular subtenses for the hexagonal bundle are much larger than those for the rectangular bundle. Figures 5 and 6 depict the two different FFOB formats used in this study as seen through the microscope by the subject.

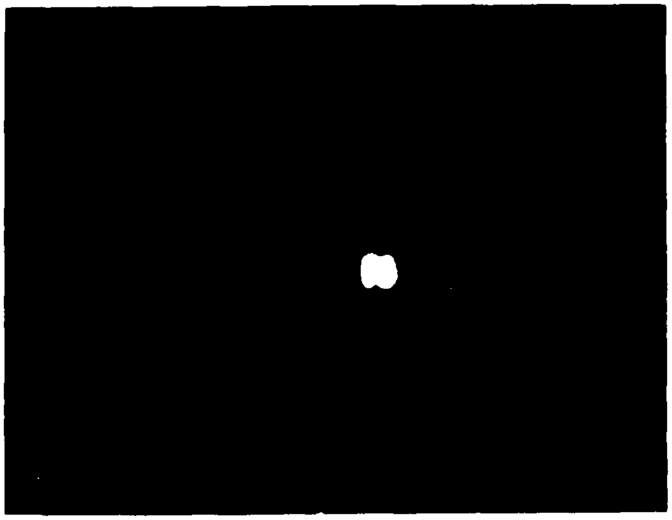

Figure 5. The hexagonal format FFOB.

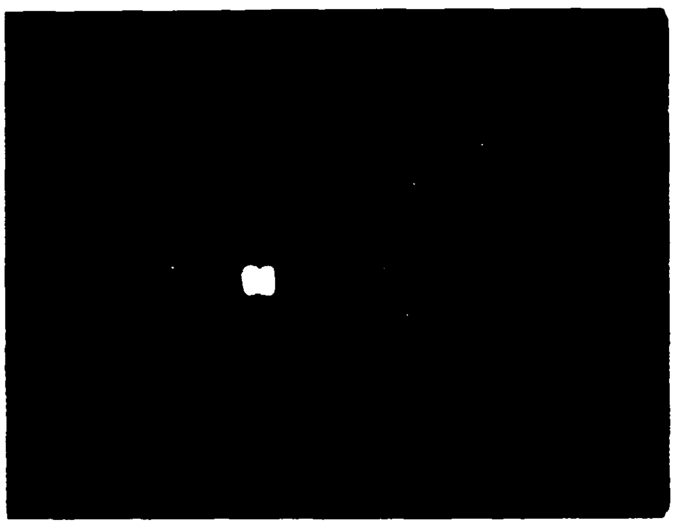

Figure 6. The reactangular format FFOB.

Table 1. Character Angular Subtense of the Various Stimulus Imagery Used.

| | Rectangular | | | Hexagonal | | |
|---|---|---|---|---|---|---|
| | Fiber Angular Subtense (Min of Arc) | | | | | |
| Elements/Letter | 1.35 | 1.69 | 2.71 | 6.75 | 8.45 | 13.55 |
| 3.2 | | | | 21.6 | 27.0 | 43.4 |
| 4.0 | 5.4 | 6.8 | 10.8 | | | |
| 4.5 | | | | 30.4 | 38.0 | 61.0 |
| 5.6 | 7.6 | 9.5 | 15.2 | | | |
| 6.2 | | | | 41.9 | 52.4 | 84.0 |
| 7.8 | 10.5 | 13.2 | 21.1 | | | |
| 8.7 | | | | 58.7 | 73.5 | 117.9 |
| 10.9 | 14.7 | 18.4 | 29.5 | | | |
| 12.2 | | | | 82.4 | 103.9 | 165.3 |
| 15.3 | 20.7 | 25.9 | 41.5 | | | |

Subjects

A total of 12 college-age subjects obtained through a paid subject pool was used. All subjects, males and females, were required to have normal or corrected vision of 20/20. All subjects were tested over a two-day period. On the first day, they were tested with the rectangular bundle and on the second they were tested with the hexagonal bundle. On each day, all subjects participated in a total of three sessions, each session corresponding to one of the magnification (10x, 12.5x or 20x) levels used. To combat possible learning and/or practice effects, the exposure of each subject to each magnification level was counterbalanced. Rest periods were provided between each session.

## Procedure

The following procedure was adhered to during the conduct of this experiment: Each subject was given an explanation of the purpose of the experiment, the task to be performed, and the manner in which he(she) was to respond. The subject was then seated in front of the microscope and allowed to adjust the focus until he(she) could see the "display" clearly. In focusing the microscope, and throughout all test sessions, subjects used their preferred eye.

After having focused the microscope, the subject was given 150 trials, 50 each under a specified magnification level. After each block of 50 trials, the subject was given a 10-minute rest period. During this rest period the experimenter changed the magnification level of the microscope. The subject was then allowed to make any adjustments necessary to refocus the microscope before beginning the next set of trials.

During a given trial, the stimulus slide was projected via an appropriate optical relay system onto one end of the FFOB and transmitted through the bundle to the "display" end. When ready, the subject depressed a start button while looking through the microscope's eyepiece. Activation of the start button simultaneously started a digital timer and opened an optical shutter which allowed the subject to see the transmitted image. When the subject had made a determination as to what letter (character) was on the display, he released the start button and called out the name of the letter. Deactivation of the start

button stopped the digital timer (which provided a measure of the subject's identification time) and closed the optical shutter. The subject's identification responses were manually recorded on appropriately prepared data sheets by the experimenter. The order of exposure of each letter to the subject was randomized.

## Section 4

## RESULTS

The results obtained are shown in Figures 7 through 10. These figures depict subject performance as a function of the number of elements across each letter for each FFOB format (rectangular and hexagonal) collapsed across magnification levels. The data points used to generate these curves are presented in Appendix I.

Figure 7 shows performance in terms of correct identifications made. Two trends are immediately apparent. First, performance improves as the number of elements across each letter increases. Performance improves on the average from 14.6% to 96% for the rectangular bundle and from 45% to 100% for the hexagonal bundle. Secondly, performance with the hexagonal bundle was far superior to that obtained with the rectangular bundle.

Figure 8 shows performance in terms of the time it took subjects to correctly identify a letter (ie, response time). As was the case for correct identifications, performance improved (responsetimes became shorter) as the number of elements per letter increased and the hexagonal bundle yielded faster response times than the rectangular bundle. For the rectangular bundle, response times initially increased from 2.85 to 4.17 seconds then gradually decreased to 1.48 seconds at the largest letter size. Thisis attributed to the fact that at this angular subtense size

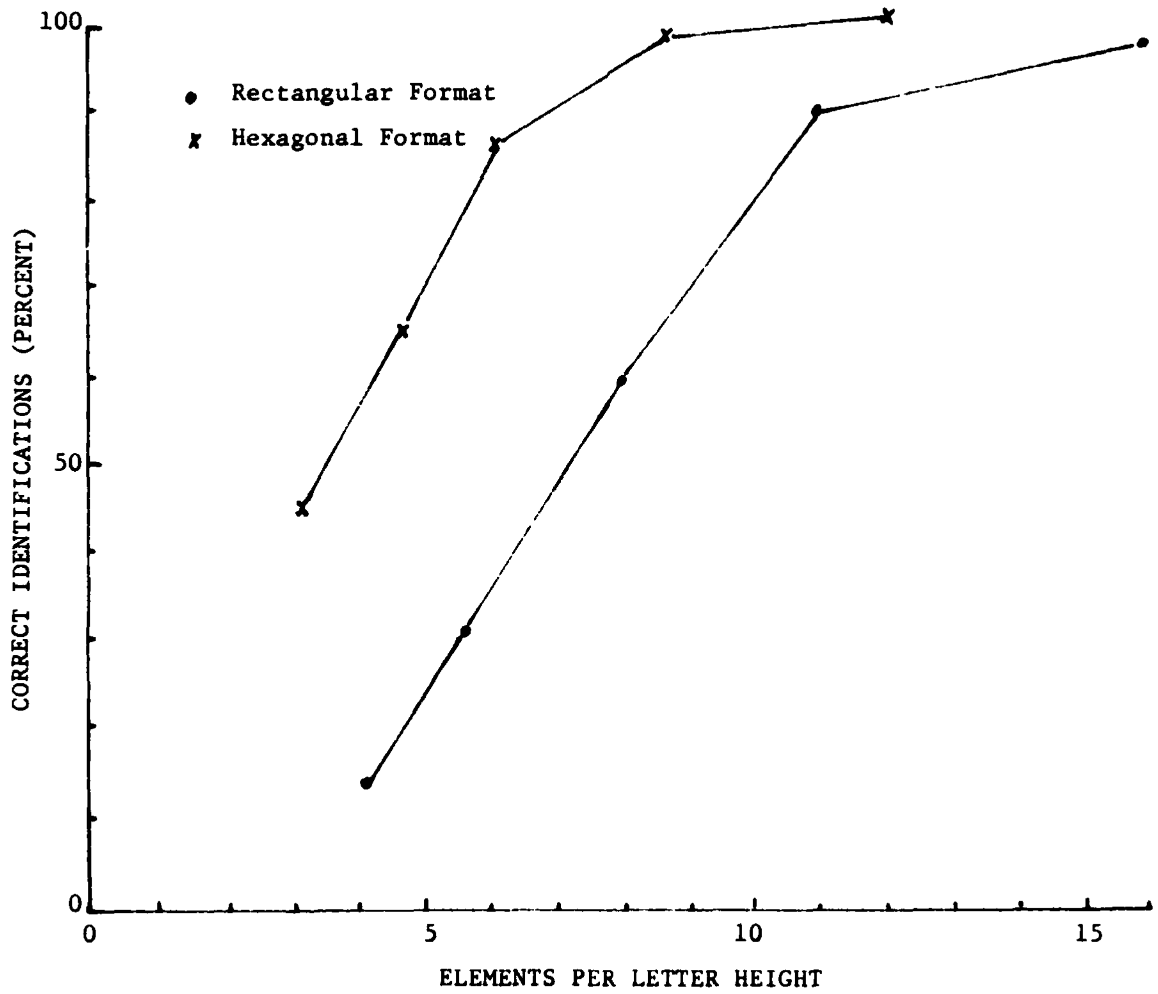


Figure 7. Percent correct identifications as a function of elements per letter height for each FFOB used.

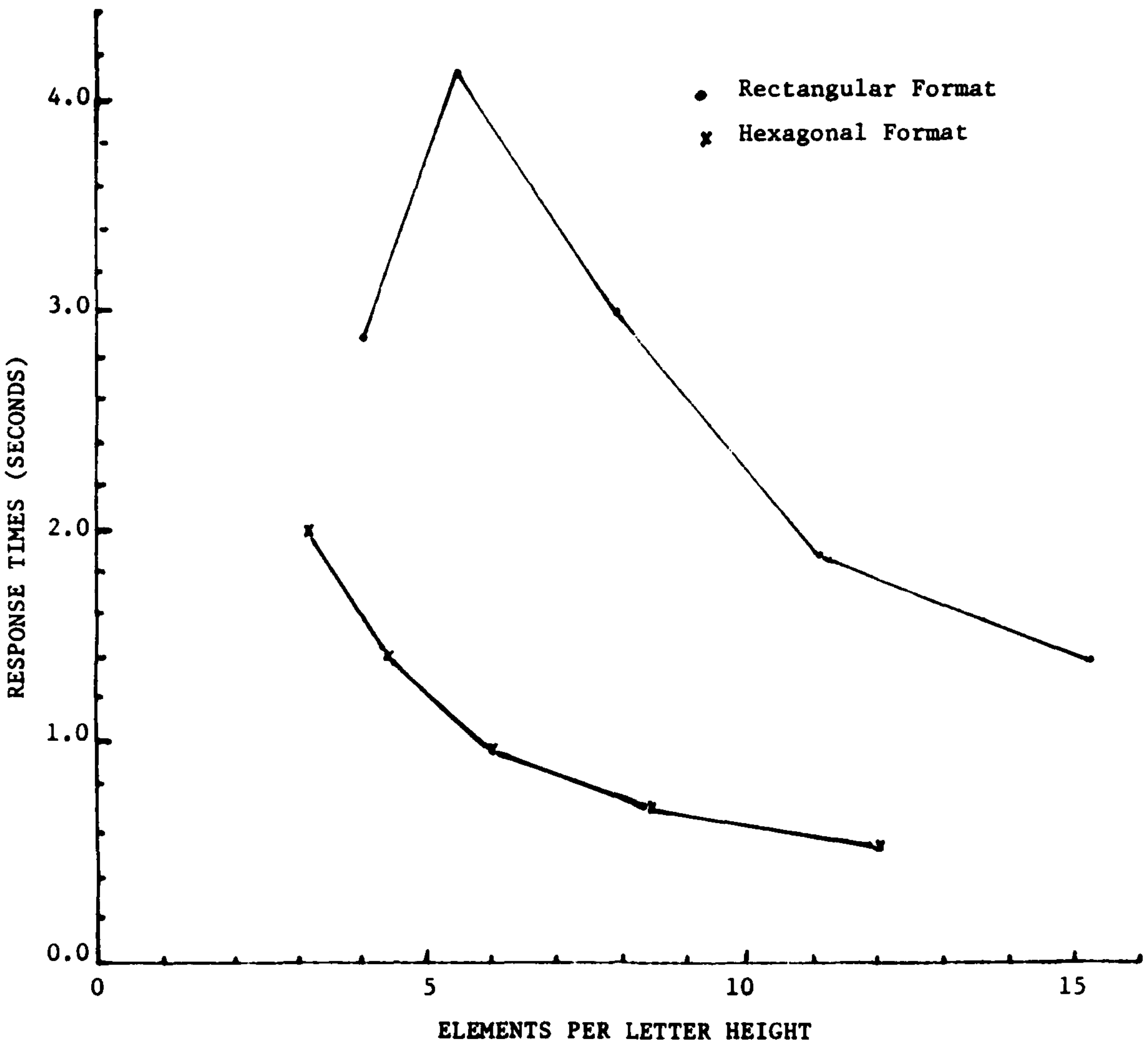


Figure 8. Operator response times as a function of elements per letter height for each FFOB used.

(5.4 min) it is suspected that subjects couldn't tell what it was so that response time was less but errors were higher. For the hexagonal bundle, response times became shorter (faster), dropping from a high of 2.01 seconds to 0.66 seconds at the largest letter size.

Figures 9 and 10 show performance in terms of false identifications and misses respectively. False identification occurred when the subject was able to see the stimulus but misidentified it. For example, reporting the letter "C" when the letter "G" was presented. Misses occurred when the subjects were unable to recognize or identify the displayed letter. For both measures, performance improved as letter size increased. The percentage of false identifications decreased from a high of 53.6% to a low of 2.3% for the rectangular bundle and from 40.3% to 0% for the hexagonal bundle. The percentage of misses decreased from 33% to 0% (at the fourth largest letter size) for the rectangular bundle and from 11.6% to 0% (at the third largest letter size) for the hexagonal bundle. For both measures, performance with the hexagonal bundle was superior to that attained with the rectangular bundle. However, part of this superiority was undoubtably due to the difference in angular subtense of the total character that was necessary due to the different individual fiber sizes that were available. It is difficult to separate effects due to angular subtense of the letters from effects due to hexagonal vs rectangular bundles.

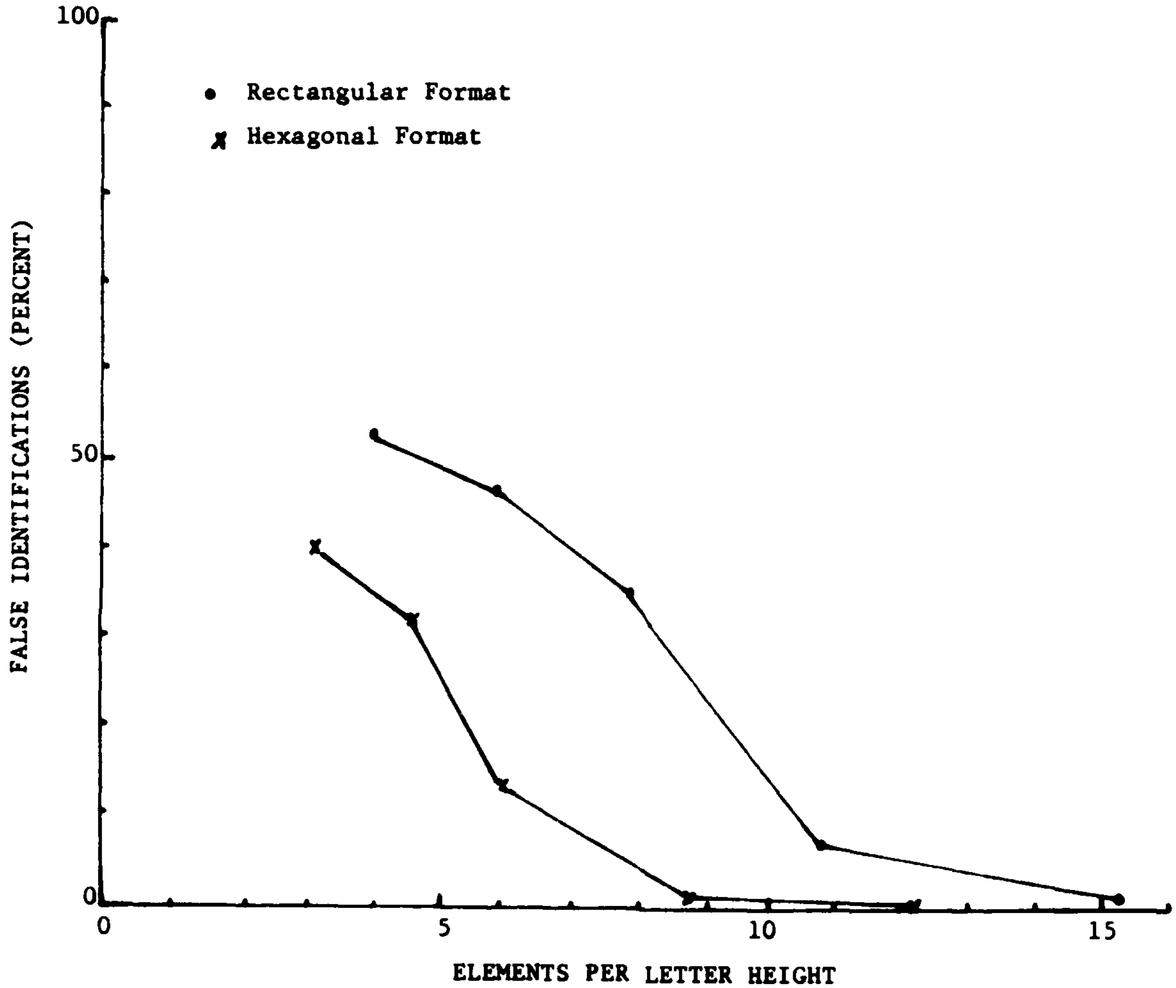


Figure 9. Percent false identifications for each FFOB as a function of elements per letter height.

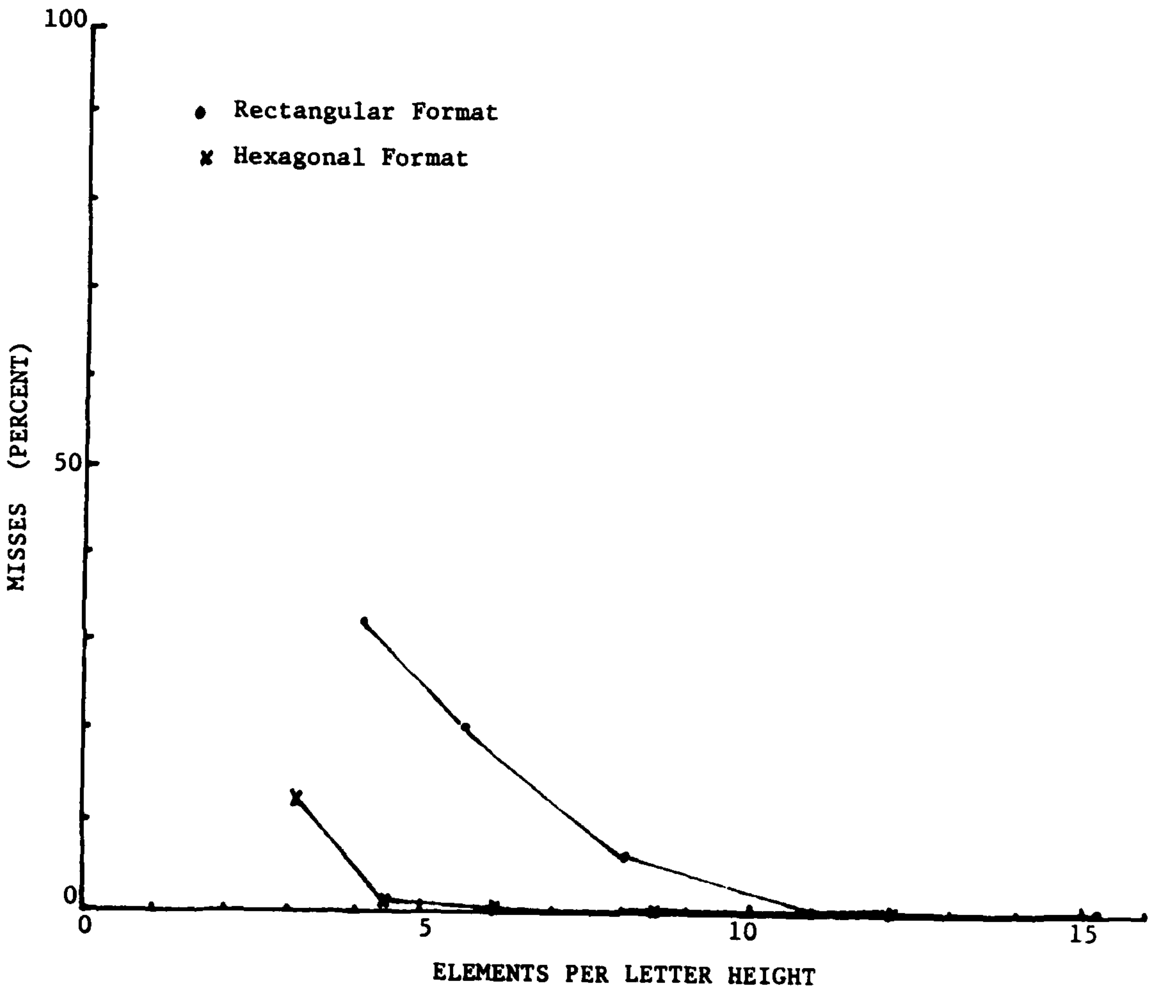


Figure 10. Percent misses as a function of elements per letter height for each FFOB used.

## Section 5

## DISCUSSION

Two major findings are apparent from the results of this study. First, performance improved as the number of elements per letter height increased and, secondly, performance with the larger character angular subtense letters (hexagonal format) was superior to that obtained with the smaller character angular subtense letters (rectangular format).

With respect to the latter finding, the superiority of the hexagonal bundle can be explained in terms of the difference in physical characteristics of the bundles used. It will be recalled that the fibers in the rectangular bundle were 10-micron in size while the fibers for the hexagonal bundle were 50-microns. Under the magnification levels used (10x, 12.5x and 20x), the fiber angular subtenses for the rectangular bundle were 1.35, 1.69 and 2.71 minutes of arc respectively. For the hexagonal bundle, the fiber angular subtenses were 6.75, 8.45 and 13.55 minutes of arc or approximately 5 times larger than that for the rectangular bundle. This resulted in character angular subtenses that were approximately 4 times larger for the hexagonal bundle as compared to the rectangular bundle. This difference in angular subtense obviously made it much easier to "see" and, hence, much easier to identify the characters displayed on the hexagonal bundle. The results obtained seem to support this supposition.

Although this finding is of interest, it should be remembered that the primary objective of this study was to determine what effect the number of elements across a given letter would have on that letter's legibility/readability. That is, its property to be easily recognized and assigned to its proper literal category by an observer. This property is of course dependent on the fact that the stimulus letter is of sufficient size (has adequate angular subtense) and has adequate displayed details (resolution).

As indicated in Table 1, the number of elements per letter height increased from 3.2 to 15.3 (3.2, 4.5, 6.2, 8.7 and 12.2 for the hexagonal bundle and 4.0, 5.6, 7.8, 10.9 and 15.3 for the rectangular bundle). Also presented in Table 1 are the angular subtenses of the various stimulus letters used. These angular subtenses are seen to increase not only as a result of the increase in elements per letter height but also (within a given elements per height category) as a result of the magnification level employed. The resulting angular subtenses ranged from a minimum of 5.4 to a maximum of 165.3 minutes of arc. Since the human eye is capable of identifying the letters of the alphabet if they subtend 5 minutes of arc (Grether and Baker, 1972), the angular subtenses of the stimulus letters used were well within the visual capabilities of the subjects to detect and identify them given sufficient resolution.

A review of the pertinent literature dealing with image size suggests that the recommended symbol size should be greater than

20 minutes of arc. For example, Grether and Baker (1972) state that although a 12 minute of arc target image is recognizable under laboratory conditions, under operational conditions it should subtend at least 20 minutes of arc before it is recognizable. Ketchel and Jenny (1968) in their review of the literature dealing with HUD research indicate that symbol sizes of 24 to 35 minutes of arc are commonly found on contemporary HUDs. Kama et al (1976) using symbol sizes ranging from 21 to 35 minutes of arc found that a reduction in symbol size by as much as 30% did not significantly affect the ability of an operator to correctly read information from a HUD (altitude, air speed and pitch angle) while performing a compensatory tracking task.

Also playing an important role in target recognition is resolution. Assuming an adequate angular subtense (as was the case in this study) of the target image so that the resolving power of the eye is not the limiting factor, the amount of displayed detail has a significant effect upon the observer's ability to recognize and identify a target. Johnson (1958), using the minimum dimension of various vehicle-type targets, found that 8.0 1.6 TV lines were required for recognition while 12 - 3.0 TV lines were required for identification. Baker and Nicholson (1967), using alphanumeric stimuli that subtended 30 minutes of arc, found that 7 raster lines or more were required before 90% recognition performance was achieved. Grether and Baker (1972) suggest that for mosaic-type displays, alphanumeric characters can be reproduced reasonably well using matrix rows

which are 5 cells in height. Such characters can be readily identified and are not easily confused.

Having determined what the recommended image size (in angular subtense) and elements per image height (resolution) should be for optimum performance in a recognition task, it becomes of interest to examine our findings in light of the data presented in the previous paragraphs. As noted earlier, performance with respect to all four dependent variables improved as the number of elements per letter height increased (see Figures 10, 11, 12 and 13). This was true for both the rectangular and hexagonal format FFOBs. However, by examining (in depth) the data presented in Appendix I, we can obtain a better understanding as to the influence elements per letter height and character angular subtense had on subject performance. Additionally, a clearer picture will emerge with regard to the relationship of the data obtained in this study with that in the existing literature.

If one looks at the data for the hexagonal format FFOB (where character angular subtense equaled or exceeded the minimum 20 minutes of arc recommended by previous researchers), it becomes apparent that the overriding variable which determined performance was elements per letter height. For all four performance measures used (percent correct identification, response time for correct identification, percent misses and percent false identification), near optimal performance was achieved at 8.7 elements per letter height. For the rectangular

format FFOB, near optimal performance did not occur until elements per letter height reached 10.9 elements and character angular subtense exceeded 18 minutes or arc. It is also of interest to note that no misses occurred when elements per letter height reached 8.7 and 10.9 elements respectively for the hexagonal and rectangular format FFOB. Additionally, at 10.9 elements per letter height, false identifications occurred at a 10% rate for the rectangular format bundle while no false identifications occurred for the hexagonal bundle at 8.7 elements per letter height. Based on these observations, it is concluded that the findings from this study compare most favorably with the data in the relevant existing literature and that it is further recommended that alphanumerics displayed via a fiber optics bundle should have a minimum of 10 elements per letter height and subtend at least 20 minutes of arc.

## APPENDIX I

Performance as a Function of Elements/Letter Height and Character Angular Subtense for Correct Identifications, Response Times, Misses, and False Identifications.

| | Rectangular | | | | Hexagonal | | |
|---|---|---|---|---|---|---|---|
| | Fiber Subtense | | | | Fiber Subtense | | |
| Elem/Letter | 1.35 | 1.69 | 2.71 | Elem/Letter | 6.75 | 8.45 | 13.55 |
| 4.0 | 5.4 | 6.8 | 10.8 | 3.2 | 21.6 | 27.0 | 43.4 |
| | (15) | (13) | (16) | | (42) | (42) | (51) |
| 5.6 | 7.6 | 9.5 | 15.2 | 4.5 | 30.4 | 38.0 | 61.0 |
| | (25) | (27) | (40) | | (69) | (67) | (62) |
| 7.8 | 10.5 | 13.2 | 21.1 | 6.2 | 41.9 | 52.4 | 84.0 |
| | (51) | (57) | (67) | | (89) | (84) | (87) |
| 10.9 | 14.7 | 18.4 | 29.5 | 8.7 | 58.7 | 73.5 | 117.9 |
| | (87) | (92) | (91) | | (99) | (99) | (99) |
| 15.3 | 20.7 | 25.9 | 41.5 | 12.2 | 82.4 | 103.9 | 165.3 |
| | (93) | (97) | (98) | | (100) | (100) | (100) |

Correct Identifications. ( ) = Per Cent

| | Rectangular | | | | Hexagonal | | |
|---|---|---|---|---|---|---|---|
| | Fiber Subtense | | | | Fiber Subtense | | |
| Elem/Letter | 1.35 | 1.69 | 2.71 | Elem/Letter | 6.75 | 8.45 | 13.55 |
| 4.0 | 5.4 | 6.8 | 10.8 | 3.2 | 21.6 | 27.0 | 43.4 |
| | (3.50) | (2.44) | (2.62) | | (2.14) | (2.18) | (1.71) |
| 5.6 | 7.6 | 9.5 | 15.2 | 4.5 | 30.4 | 38.0 | 61.0 |
| | (3.84) | (4.89) | (3.78) | | (1.43) | (1.47) | (1.29) |
| 7.8 | 10.5 | 13.2 | 21.1 | 6.2 | 41.9 | 52.4 | 84.0 |
| | (3.04) | (3.90) | (2.27) | | (1.06) | (0.93) | (1.10) |
| 10.9 | 14.7 | 18.4 | 29.5 | 8.7 | 58.7 | 73.5 | 117.9 |
| | (2.38) | (2.05) | (1.28) | | (0.81) | (0.79) | (0.69) |
| 15.3 | 20.7 | 25.9 | 41.5 | 12.2 | 82.4 | 103.9 | 165.3 |
| | (1.76) | (1.63) | (1.05) | | (0.70) | (0.70) | (0.59) |

Response Times. ( ) = RT

| | Rectangular | | | | Hexagonal | | |
|---|---|---|---|---|---|---|---|
| | Fiber Subtense | | | | Fiber Subtense | | |
| Elem/Letter | 1.35 | 1.69 | 2.71 | Elem/Letter | 6.75 | 8.45 | 13.55 |
| 4.0 | 5.4 (34) | 6.8 (36) | 10.8 (28) | 3.2 | 21.6 (16) | 27.0 ( 1) | 43.4 (18) |
| 5.6 | 7.6 (26) | 9.5 (23) | 15.2 (13) | 4.5 | 30.4 (0.2) | 38.0 (0.0) | 61.0 (0.1) |
| 7.8 | 10.5 (9) | 13.2 (8) | 21.1 (0) | 6.2 | 41.9 (0) | 52.4 (0) | 84.0 (0) |
| 10.9 | 14.7 (0) | 18.4 (0) | 29.5 (0) | 8.7 | 58.7 (0) | 73.5 (0) | 117.9 (0) |
| 15.3 | 20.7 (0) | 25.9 (0) | 41.5 (0) | 12.2 | 82.4 (0) | 103.9 (0) | 165.3 (0) |

Misses. ( ) = Per Cent

| | Rectangular | | | | Hexagonal | | |
|---|---|---|---|---|---|---|---|
| | Fiber Subtense | | | | Fiber Subtense | | |
| Elem/Letter | 1.35 | 1.69 | 2.71 | Elem/Letter | 6.75 | 8.45 | 13.55 |
| 4.0 | 5.4 (51) | 6.9 (53) | 10.8 (57) | 3.2 | 21.6 (42) | 27.0 (48) | 43.4 (31) |
| 5.6 | 7.6 (49) | 9.5 (50) | 15.2 (47) | 4.5 | 30.4 (29) | 38.0 (33) | 61.0 (37) |
| 7.8 | 10.5 (40) | 13.2 (36) | 21.1 (32) | 6.2 | 41.9 (11) | 52.4 (16) | 84.0 (13) |
| 10.9 | 14.7 (10) | 18.4 (8) | 29.5 (9) | 8.7 | 58.7 (0.1) | 73.5 (0.1) | 117.9 (0.1) |
| 15.3 | 20.7 (7) | 25.9 (0) | 41.5 (0) | 12.2 | 82.4 (0) | 103.9 (0) | 165.3 (0) |

False Identifications. ( ) = Per Cent

## REFERENCES


Baker, C.A. and Nicholson, R.M. "Raster scan parameters and target recognition." Proceedings of 19th Annual National Aerospace Electronics Conference (NAECON), 1967.

Kama, W.N., Martin, W. and Kuperman, G.G. "The effect of HUD symbology size of operator performance under various luminance conditions." Proceedings of 5th Psychology in the Air Force Symposium, April 1976.

Johnson, J. "Analysis of image forming systems." Proceedings of the Image Intensifier Symposium, October 1958.

Grether, W.F. and Baker, C.A. "Visual presentation of information." Human Engineering Guide to Equipment Design, 1972, pp 41-122.

Task, H.L. and Hornseth, J.P. "Feasibility of a flexible fiber optic bundle for helmet mounted displays." (Unpublished manuscript, 1974).




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